### Science on the International Space Station: Stepping Stones for Exploration

Julie A. Robinson, Ph.D.,
ISS Program Scientist
May 2007

14 ISS Expeditions Completed

Over 6 years of active human presence

**ISS Percent Complete by Mass**

<table>
<thead>
<tr>
<th>Date</th>
<th>Total (lbm)</th>
<th>Complete</th>
<th>Complete</th>
<th>Complete</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node 2 OOS</td>
<td>33,125</td>
<td>100%</td>
<td>863,688</td>
<td>88%</td>
<td>55%</td>
</tr>
<tr>
<td>Node 2 IMC</td>
<td>356,363</td>
<td>100%</td>
<td>1,174,472</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Node 2 IMC (or IMC)</td>
<td>356,363</td>
<td>100%</td>
<td>1,174,472</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**U.S. RESEARCH CREW TIME**

Actively Proceeded as Compared to Minimum Requirements, Minimum, and Allocations

<table>
<thead>
<tr>
<th>Week</th>
<th>Minimum (GGR&amp;C)</th>
<th>Subscription (IDRD)</th>
<th>Actuals Provided</th>
<th>Final Incr U.S.</th>
<th>U.S. Average Weekly Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1 month</td>
<td>10.0</td>
<td>14.0</td>
<td>16.0</td>
<td>18.0</td>
<td>20.0</td>
</tr>
<tr>
<td>L-1 month</td>
<td>0.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
</tr>
<tr>
<td>L-1 month</td>
<td>10.6</td>
<td>7.4</td>
<td>17.3</td>
<td>14.9</td>
<td>11.3</td>
</tr>
<tr>
<td>L-1 month</td>
<td>6.1</td>
<td>149</td>
<td>4.0</td>
<td>104</td>
<td>94</td>
</tr>
<tr>
<td>L-1 month</td>
<td>5.8</td>
<td>142</td>
<td>6.9</td>
<td>180</td>
<td>162</td>
</tr>
<tr>
<td>L-1 month</td>
<td>9.0</td>
<td>7.2</td>
<td>212</td>
<td>3.1</td>
<td>72</td>
</tr>
</tbody>
</table>

**Notes**

- Increment 14 requirement (subscription) of 212 hours was later reduced to 170 based on successful completion of research requirements in earlier Increments.
- Initial Incr 15 requirement (subscription) of 212 hours was later reduced to 170 based on successful completion of research requirements in earlier Increments.
- Minimum Requirements, Subscriptions, and Allocations.

**Legend**

- L-1 Month: Most Recent to Launch
- OOS: On-Orbit Operations Summary
- IMC: Increment Definition and Requirements Document
- Pod: Rod Jones/OZ
- GGR&C: Generic Groundrules, Requirements & Constraints
- 10.0+: 10.0+ hours
- 10.0+: 14.0+ hours
- 10.0+: 16.0+ hours
- 10.0+: 18.0+ hours
- 10.0+: 20.0+ hours

**Average Weekly Total**

- Minimum Requirement (GGR&C) to date
- Minimum Requirement (GGR&C) to date
- Minimum Requirement (GGR&C) to date
- Minimum Requirement (GGR&C) to date
- Minimum Requirement (GGR&C) to date
- Minimum Requirement (GGR&C) to date

**Minimum Requirements, Subscriptions, and Allocations**

<table>
<thead>
<tr>
<th>Minimum Requirement (GGR&amp;C)</th>
<th>Subscription (IDRD)</th>
<th>Actuals Provided</th>
<th>Final Incr U.S.</th>
<th>U.S. Average Weekly Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>14.0</td>
<td>16.0</td>
<td>18.0</td>
<td>20.0</td>
</tr>
<tr>
<td>10.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
</tr>
<tr>
<td>10.0</td>
<td>149</td>
<td>4.0</td>
<td>104</td>
<td>94</td>
</tr>
<tr>
<td>5.8</td>
<td>142</td>
<td>6.9</td>
<td>180</td>
<td>162</td>
</tr>
<tr>
<td>9.0</td>
<td>7.2</td>
<td>212</td>
<td>3.1</td>
<td>72</td>
</tr>
</tbody>
</table>

**Final Incr 14 U.S. utilization Saturday Science crew time cumulative total**

- Final Incr 14 U.S. utilization Saturday Science crew time increased to 313 hours.
- Notes

**Introduction to ISS**

- International Space Station Program Office
- Lauren Walls/281-244-8096/OM3/VIPeR

**Dimensions**

- Weight:
  - Core Node 2: 475,363 lbs
  - International: 33,125 cubic feet

**Volume**

- 356 ft³ Width: 114 ft Length: 170 ft Height: 114 ft Weight: 33,125 lbm Volume: 33,125 cubic feet

**Notes**

- Assembly complete
- Complete
- Complete
- Complete
- Complete
- Complete
- Complete
- Complete
- Complete
- Complete
ISS Research Accommodations Status

11 May 2007 (Data through 30 April 2007) [PSC Red Journal]0

Research Outfitting

Human Research Facility (HRF) Racks

HRF-1

HRF-2

HRF-3

HRF-4

HRF-5

HRF-6

ER-1

ER-2

ER-3

ER-4

ER-5

ER-6

ER-7

ER-8

ER-9

ER-10

ER-11

ER-12

ER-13

ER-14

ER-15

ER-16

ER-17

FSL

EMCS

EDR

OOS

MSG

IP

International Partner

IDRD

HRF

FSL

EXPRESS Rack

ER

European Modular

EMCS

EDR

Laboratory Freezer for ISS

Requirements Document

Research Mass to Orbit

Research Crew Time Total

2012 / 78

726.3

724.0

724.0

726.3

116 / 102

121 / 142

159 / 148

173 / 178

276 / 197

11.3 / 4.4

4.5 / 4.0

5.3 / 6.2

6.1 / 5.4

7.4 / 7.6

10.6 / 7.6

[Image]

ISS Major Pressurized Science Outfitting

Rev N Assembly Sequence, 2007

NASA

ESA

JAXA

Nine NASA Research Racks On Orbit

- 2 Human Research Facility (HRF) Racks
- Biomedical investigations, including ultrasonic body mass measurement, resolution dose studies, physiology modeling, ambulatory blood pressure measurement, physical activity and equipment unique hardware
- 5 Multi-User EXPRESS (MUE) Racks
- Modular design, allowing investigations in various research areas in dedicated racks
- Microgravity Sciences Glovebox (MSG)
- Microgravity materials and fluid experiments to date
- Microgravity Materials Science (MMS)
- Provides thermal conditioning at +4°C, -20°C and -60°C

Planned NASA Research Facilities

NASA pressurized payload rack facilities awaiting launch

  - Facility dedicated to research in combustion science
- Space Dynamically Responding Ultrasonic Matrix System (SpaceDRUMS) (2008)
  - EXPRESS-based containerized (ultrasound) processing facility
- EXPRESS Rack 6 (2008)
  - Multipurpose payload facility, may also house ISS Gallery elements
Planned NASA Research Facilities

**NASPs**

- **Microgravity Science Research Rack (MSRR) (2009)**
  - Facility to support ESA Microgravity Science Lab experiments
- **Fluids Integrated Rack (FIR) (2009)**
  - Facility dedicated to fluid physics research, with Light Microscope Module
- **Window Observation Research Facility (WORF) (2009)**
  - Facility to support visual and multispectral remote sensing using Lab Optical Window
- **Muscle Atrophy Research Exercise System (MARES) (2009)**
  - Facility for muscle, skeletal, biomechanical, neuromuscular and neurological physiology measurements

---

**Columbus**

Research racks launched in Columbus

- **European Physiology Module**
  - Facility for human physiology research in neuroscience, cardiorespiratory, bone and muscle metabolism
- **Fluid Science Lab**
  - Multi-user facility for fluid physics research
- **Biolab**
  - Facility for cell culture, tissue, microorganisms, small plants and animals research
- **European Drawer Rack**
  - Facility for small-class experiment and storage
- **European Transport Carrier**
  - Storage and transportation rack for experiments

External facilities launched with Columbus

- **European Technology Exposure Facility (EuTEF)**
  - Provides a platform for investigating future science data on the ISS space environment
- **SOLAR**
  - A platform with coarse pointing capability for three-sciences instruments to monitor the solar flux in different wavelengths

---

**Kibo**

Research racks launched with pressurized elements or later on HTV

- **RYUKA (2008)**
  - Fluid physics and growth research, biological research processing unit
- **SILABO (2008)**
  - Cell biology facility, contains cell biology experiment facilities, including microscope, centrifuge
- **KIBO (2009)**
  - Gradient Heating Furnace for materials processing research

External payloads launched with JEM-EF or later on HTV

- **Space Environment Data Acquisition (SEDA) (2009)**
  - Monitor neutrons, plasma, atomic oxygen, and heavy ions
- **Monitor All-sky X-ray Image (MAXI) (2009)**
  - Monitor X-ray bursts by Gas Detectors Camera and X-ray CCD Camera
- **Superconducting Sub millimeter-wave Limb-Emission Sounder (SMILES) (2009)**
  - Demonstrate sub-mm wave sensor technology and conduct sub-mm wave-emission sounding of the atmosphere for measurement of trace gases in the stratosphere

The NASA Authorization act of 2005 designated the U.S. facilities and resources on the ISS as a “national laboratory” (Public Law 109-155, Sec. 507)

- Directed NASA to develop a plan to “increase the utilization of the ISS by other Federal entities and the private sector”...
- As the Nation’s newest national laboratory, the ISS will further strengthen relationships among NASA, other Federal entities, and private sector leaders in the pursuit of national priorities for the advancement of science, technology, engineering, and mathematics.
- The ISS National Laboratory will also open new paths for the exploration and economic development of Space.
- Opportunity to expand the US economy in space-based research, applications and operations.
- "Unique and highly visible national asset with surplus capacity available for a wide spectrum of applications"...
- NASA will continue to cover cost of operating and maintaining the ISS, and is highly motivated to work in other agencies and organizations to pursue applications.

---

**Japanese Aerospace Exploration Agency (JAXA)**

Research racks launched with pressurized elements or later on HTV

- **RYUKA (2008)**
  - Fluid physics and growth research, biological research processing unit
- **SILABO (2008)**
  - Cell biology facility, contains cell biology experiment facilities, including microscope, centrifuge
- **KIBO (2009)**
  - Gradient Heating Furnace for materials processing research

External payloads launched with JEM-EF or later on HTV

- **Space Environment Data Acquisition (SEDA) (2009)**
  - Monitor neutrons, plasma, atomic oxygen, and heavy ions
- **Monitor All-sky X-ray Image (MAXI) (2009)**
  - Monitor X-ray bursts by Gas Detectors Camera and X-ray CCD Camera
- **Superconducting Sub millimeter-wave Limb-Emission Sounder (SMILES) (2009)**
  - Demonstrate sub-mm wave sensor technology and conduct sub-mm wave-emission sounding of the atmosphere for measurement of trace gases in the stratosphere
ISS Event Horizon for National Laboratory Implementation

Calendar Year

National Lab Plan | Assembly Complete | Shuttles Retirement | Service Life Extension Decision | Current Service Life End

Preparatory Window | Assembly Operations | Service Operations (5 years)

Science Accomplishments on ISS

“Early utilization” on ISS

- Science completed during assembly
- Early returns during the course of assembly
- Takes advantage of assembly delays, extra crew time
- Means that every crewmember on ISS can be a subject for human research experiments
- More human experiments and larger sample sizes over the life of ISS
- Provides information on the potential uses of ISS after assembly is complete

Expedition 14 Research Accomplishments (September 2006 – April 2007)

- Expedition 14
  - 34 U.S.-integrated investigations
  - 8 completed investigations
  - 139 scientists
- Expeditions 0-14 (May 2000-April 2007)
  - 112 U.S.-integrated investigations
  - 80 completed investigations
  - 373 scientists


- Expedition 15 Plans
  - 38 U.S.-integrated investigations
  - 11 new investigations
  - 1 reserve investigation
  - 139 scientists

U.S. Investigations on ISS


Outside U.S.: 39

Expedition 14 Research Accomplishments

- Expedition 14
  - 34 U.S.-integrated investigations
  - 8 completed investigations
  - 139 scientists
- Expeditions 0-14 (May 2000-April 2007)
  - 112 U.S.-integrated investigations
  - 80 completed investigations
  - 373 scientists


- Expedition 15 Plans
  - 38 U.S.-integrated investigations
  - 11 new investigations
  - 1 reserve investigation
  - 139 scientists
ISS Educational Accomplishments

- K-12 Student participation on ISS 2000-2006
- 66,000 students in inquiry based learning with ISS data
- 800,000 students with classroom versions of ISS experiments
- 31 million had the opportunity to see telecasts from ISS
- 470 undergraduate students
- 251 graduate and postdoctoral students

The Vision for Space Exploration and The ISS National Laboratory

1. Complete assembly of the ISS
2. Develop Orion (Crew Exploration Vehicle)
3. Utilize ISS

The Vision for Space Exploration

On January 14, 2004, the focus of NASA research on ISS was fundamentally changed with President Bush’s Vision for U.S. Space Exploration

- ISS Focus for NASA before Exploration Vision: Diverse, multi-discipline research
  - Human Life Sciences
  - Biological Sciences
  - Materials Science
  - Fluids Science
  - Combustion Science
  - And all other sciences!

NEW ISS Focus for NASA
- Astronaut health and countermeasure development to protect crews from the space environment during long duration voyages
- Testing research and technology developments for future exploration missions
- Developing and validating operational procedures for long-duration space missions

ISS Medical Project
Experiments on ISS can address:

**SPACE SYSTEM**
- Advanced life support
- Exercise systems
- Clinical capabilities
- Radiation
- Dust

**HUMAN SYSTEM**
- Integrated physiology
- Cardiovascular
- Bone & Muscle
- Neurovestibular
- Food and nutrition
- Immunology & infection
- Human behavior & performance
ISS Medical Project

- ISSMP has been developed to maximize the utilization of ISS to obtain solutions to the human health and performance problems and the associated mission risks of exploration class missions.
- Complete programmatic review with medical operations (space medicine/flight surgeons) to identify:
  - Evidence base on risks
  - Gap analysis
- Rapid implementation of key studies to optimize human research return.

Disciplines Represented in early ISS Research

- Human Research
- Cell Biology and Biotechnology
- Plant Biology
- Physical Sciences
- Technology Development
- Environmental Monitoring
- Earth Observation
- Education

NASA mission-driven Research and the National Laboratory

- ISS for Exploration (NASA mission)
  - Human Research for Exploration
  - Exploration Technology Development
  - Space Operations Improvement
- ISS National Laboratory (Missions of many agencies and organizations)
  - Basic physiology
  - Biology and Biotechnology
  - Physical Sciences
  - Education

Bridging work:
- Microgravity Set-aside
- Education
- Earth Observations